Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal

Section 1. General administrative information

Evaluate Predator Control And Provide Technical Support For PATH

Bonneville project number, if an ongoing project 9007800

Business name of agency, institution or organization requesting funding
U.S Geological Survey, Columbia River Research Laboratory

Business acronym (if appropriate) USGS

Proposal contact person or principal investigator:

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Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name

NPPC Program Measure Number(s) which this project addresses.
5.7, 5.7A, 5.7B (Predation), 3.2C, 3.2F (PATH Support)

NMFS Biological Opinion Number(s) which this project addresses.
NMFS Biological Opinion (1995), Section IV Project Effects, Part 5 Squawfish Removal Program (p. 64)

Other planning document references.
NMFS Proposed Recovery Plan for Snake River Salmon (1995). Task No. 2.8b. "Conduct research to determine the extent of predation problems and evaluate predation control measures".

Subbasin.

Short description.
Examine existing data to test the hypothesis that compensatory predation on juvenile salmon is not occurring in response to northern squawfish removals. Provide analyses and technical support for PATH .

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction		Watershed
*	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production	*	Population dynamics
	Oceans/estuaries	X	Research	X	Ecosystems
	Climate	*	Monitoring/eval.		Flow/survival
	Other		Resource mgmt		Fish disease
			Planning/admin.		Supplementation
			Enforcement		Wildlife habitat enhancement/restoration
			Acquisitions		

Other keywords.
predation, predator removal, modeling, PATH

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship
9007700	Northern Squawfish Management Program	Provide supporting analyses to cooperating agencies.
9600600	PATH - Facilitation and Technical Assistance; ESSA Technologies	Provide analyses, data, reports, etc. for the PATH group. Attend meetings and workshops.
9601700	Technical Support for PATH; Don Chapman Consulting	Provide assistance with fall chinook salmon analyses
9600800	PATH - Participation by state and tribal agencies; ODFW	Provide assistance with fall chinook salmon and steelhead analyses

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Evaluate the feeding response of northern squawfish and smallmouth bass to predator removal	a	Collect and organize existing data from past and ongoing studies.
		b	Test hypothesis that predators in the system do not respond to changes in predator density or average predator size (effects of predator removal program).
2	Provide technical support for PATH analyses	a	Provide data and analyses upon request of PATH members.
		b	Attend PATH meetings and workshops as needed.

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	3/1998	9/1999	50.00%
2	3/1998	9/2001	50.00%
			TOTAL 100.00%

Schedule constraints.
No constraints foreseeable.

Completion date.
2001

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel	Primarily J. H. Petersen	$29,030

Fringe benefits	28% of personnel costs	$8,124
Supplies, materials, non-expendable property	Software	$ 500
Operations & maintenance		
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		
PIT tags	# of tags:	
Travel	Workshops, non-local meetings	$2,000
Indirect costs	Agency rate: 38% of direct costs	$15,069
Subcontracts		
Other		
TOTAL		$54,723

Outyear costs

Outyear costs	**FY2000**	**FY01**	**FY02**	**FY03**
Total budget	$40,000	$40,000		
O&M as % of total	0.00%	0.00%	0.00%	0.00%

Section 6. Abstract

Work in this project falls into two objectives: 1) conduct an analysis of existing data to test the hypothesis that removal of northern squawfish does not cause compensatory feeding by predators that remain in the system, and, 2) provide technical assistance to PATH. Predation is recognized as the primary source of mortality for juvenile salmon passing through the mainstem Snake and Columbia rivers, aside from direct dam mortality. The Fish and Wildlife Program, *Return to the River*, and other regional planning documents support the northern squawfish management program, but recent evaluations acknowledge that feeding compensation could reduce some of the benefits of the program. We propose to conduct analyses of pre- and post-removal data (1983-86 versus 1993-96) on the local density of predators, feeding rates on juvenile salmon, and diets of predators. Results could be used to corroborate the efficiency of the current removal efforts or to plan and adjust future efforts.

For the second objective, staff will provide technical assistance to PATH for spring and fall chinook salmon and steelhead. Assistance will be in the form of meeting and workshop attendance, data, data analyses, and possibly research plans. Results will be incorporated into PATH analyses and documents.

Section 7. Project description

a. **Technical and/or scientific background**.

Northern squawfish *Ptychocheilus oregonensis* consume juvenile salmonids in rivers, lakes, and reservoirs in Washington, Oregon, Idaho, California, and British Columbia (Ricker 1941; Buchanan et al. 1981; Ward et al. 1995). Northern squawfish were identified as the major source of mortality away from dams in the mainstem Columbia and Snake Rivers by BPA-funded studies during the last 15 years (Poe et al. 1991; Vigg et al. 1991; Rieman et al. 1991; Ward et al. 1995; and many others).

Since the early 1940's, management programs have been implemented in several systems to remove northern squawfish, with hopes of improving the survival of juvenile salmonids (e.g., Ricker 1941; Jeppson and Platts 1959). Modeling studies suggested that removal of 20% of the predators in the Columbia and Snake rivers would result in a 50% decrease in predation-related mortality of outmigrating salmonids (Rieman and Beamesderfer 1990). These model predictions, and other studies, led to the development of a northern squawfish management program in the mainstem rivers supported by regional planning groups (NWPPC Fish & Wildlife Program 5.7; Biological Opinion Section IV, Part 5). The largest component of the predator management program has been focused on removing northern squawfish from throughout the system (Beamesderfer et al. 1996). Over 1 million predators have been removed from the system and the program has cost over $25 million. The NWPPC supported continuing the program in 1998, although they recognized its "high cost" and that predation losses may be largely related to "stresses caused by the hydrosystem itself" (unpublished recommendations of the NWPPC, NWPPC Website).

A recent evaluation of the predator removal program considered background assumptions, exploitation rates that have been achieved, and some potential compensatory responses of predators that remain in the system (Beamesderfer et al. 1996). This review concluded that predator removals were beneficial, but expressed some concern for potential compensatory responses (growth, reproduction, or predation rate) by northern squawfish or other piscivores in the river system. Increased feeding by predators in the river, in response to removal of some of their competitors through the removal program, is possible and is an unstudied aspect of predation in this system. Compensatory or density-dependent responses by predatory fish in other systems has been extensively reviewed and documented (reviewed in Saila et al. 1987 and Jude et al. 1987). Preliminary analyses of data on northern squawfish predation in John Day Reservoir suggests that local changes in predator density may cause an increased rate of consumption of juvenile salmon by those predators that remain in the area (Petersen 1997).

The second Objective of this proposal is to provide technical support to PATH. PATH analyses are intensifying as efforts are switching to fall chinook salmon and steelhead. Staff at USGS have been involved in many studies on the life history of fall chinook salmon (Rondorf and Tiffan 1997) and predation on fall chinook salmon and steelhead. We expect that PATH will request assistance during the coming year from USGS's Columbia River Research Laboratory (USGS/CRRL) staff for data analysis, technical advice, and suggestions for future research.

b. **Proposal objectives**.

Objective 1. Evaluate the feeding response of northern squawfish and smallmouth bass to predator removal. Predator removal has produced changes in the number and local density of predators in the system, which may cause changes in predation rates on juvenile salmonids by those predators that remain. We propose to examine existing data for patterns that would test the null hypothesis that "*Predator removal of the magnitude being implemented in the system does not produce a compensatory feeding response by northern squawfish or smallmouth bass*". Products of this analysis will be statistical tests, graphs, and models that address this null hypothesis (see Methods).

Objective 2. Support PATH analyses. Staff of the Columbia River Research Laboratory have been called upon to support the PATH process during the last 18 months. Support has been in the form of data requests, meeting attendance, workshops, and technical assistance on predation-related issues that PATH has addressed. We anticipate increased participation in the PATH process during the next 18 months as fall chinook salmon and steelhead are examined. Funding for this objective would be directed to support staff participation in requests from PATH members and workgroups. Products from this objective will be integrated into the overall PATH products (model analyses, reviews, etc.).

c. Rationale and significance to Regional Programs.

Objective 1. Predation by northern squawfish and smallmouth bass has been identified as the most important cause of mortality for juvenile salmon aside from dam passage mortality (e.g. Rieman et al. 1991). The FWP, *Return to the River*, the Snake River Recovery Plan and other regional documents acknowledge the important role of predators in the system. The northern squawfish management program aimed at controlling the mortality of juvenile salmonids caused by predators. The NWPPC and resource agencies need analyses to evaluate the predator control program so it may be managed for maximum benefit.

Objective 2. PATH technical support from USGS/CRRL could fall into several areas: 1) Predation on fall chinook salmon and steelhead, 2) life history and habitat information for fall chinook salmon, and 3) the role of stress and disease as mechanisms that may cause delayed mortality. Scientists at the CRRL have been conducting research on these topics for over 15 years, and publications have been produced on the magnitude of predation (cited above), physical stress (Mesa 1994), descaling and predation (Gadomski et al. 1994), prey size and condition (Petersen and DeAngelis 1992; Mesa et al. 1994), and fall chinook salmon life history (Rondorf and Tiffan 1997). Other scientists within our agency have also conducted research on stress, transportation, and disease (C. Shreck, R. Pasco, D. Elliott, e.g.) could be called upon to offer technical service.

d. Project history

This project (9007800) originated as a joint research project with the Oregon Department of Fish & Wildlife (ODFW) in the early 1980's and has produced significant products during four phases:

1. During 1983-88, the projects examined several aspects of predation by piscivores in the John Day Reservoir (population size, distribution, predation rates, diets, salmonid mortality). Several reports and over 15 peer-reviewed publications resulted from this work. These studies led to development of the predator removal program and further consideration of predation at dams.

2. During 1990-93, a joint project with USGS, ODFW and Washington Department of Fish & Wildlife was conducted to index the magnitude of predation throughout the Snake and Columbia river reservoirs. This work produced annual reports and several peer-reviewed publications that further described predation (Tabor et al. 1993; Poe et al. 1994; Ward et al. 1995; Shively et al. 1996). Methods and results developed during these studies by USGS have been used in ongoing predation evaluations (e.g. Ward et al. 1995; Beamesderfer et al. 1996).

3. During 1993-98, we examined the mechanisms that may be regulating reproductive success of northern squawfish in the Columbia River. Four annual reports were produced, 1 peer-reviewed journal article is in press (Gadomski and Barfoot *In press*), 2 manuscripts are in review at journals, and several manuscripts are in preparation.

4. Thoughout the duration of the project, studies have been conducted to better understand the mechanisms regulating predation on juvenile salmon, such as light intensity, prey density, predator size, and other factors (e.g., Faler et al. 1988; Petersen and DeAngelis 1992; Petersen and Gadomski 1994; Cech et al. 1994; Petersen and Ward *In review*).

e. **Methods**.

Methods are described for Objective 1 only, since Objective 2 is a support task for PATH activities and we cannot anticipate the specific PATH requests or analyses.

Objective 1 will be a review and analysis of existing data to test the null hypothesis: "*Predator removal of the magnitude being implemented in the system does not produce a compensatory feeding response by northern squawfish or smallmouth bass*". We have broken the methods into a description of data, models, and tests.

Data -- Consumption data used in this study were originally described by Poe et al. (1991) and Vigg et al. (1991). Sampling for squawfish was conducted by boat electroshocking in three areas of John Day Reservoir - the tailrace of McNary Dam, two mid-reservoir areas (pooled for analysis here; see Petersen 1994), and the forebay of John Day Dam. Transects were run along both shores of the reservoir during day and night periods. All squawfish were collected during 15-min transects that generally covered 0.5 to 1.0 km along a shoreline; the distance covered along a transect was affected by local variations in water current, obstructions, and the time required to dip shocked fish from the water. Northern squawfish were killed and weighed, and their digestive tract (gut) was removed for laboratory analysis. Gut contents were sorted to the lowest taxa or group and weighed. Juvenile salmonids were identified using diagnostic bones (Hansel et al. 1988). Per capita consumption rate (# salmon prey / pred / day) of salmonids was computed for each individual predator as the sum of 1/digestion time (Windell 1978; Rieman et al. 1991):

$$Ci = n(24/DT) \qquad (3)$$

where Ci is the consumption rate for individual i, n is the number of smolts in the predator's gut, and DT is evacuation rate. See Ward et al. (1995) for discussion of this methodology.

Models of compensatory feeding -- A compensatory response to predator density can occur through either direct interference between individual predators (fighting, kleptoparasitism, etc.) or through behavioral responses of prey to predators in a local area (hiding, dispersion, schooling, etc.). Both of these process are common in vertebrate and invertebrate species (see citations in Sutherland 1996) and both kinds of interactions necessarily occur over relatively short distances.

A compensatory response can be modeled as the decline in searching efficiency of predators with increasing predator density:

$$a = QP^{-m} \qquad (1)$$

where a is searching efficiency, Q is the Quest constant, P is predator density, and m is the coefficient of interference (Hassell and Varley 1969). To estimate the parameters of equation 1 using field data, a is often replaced by some measure of consumption rate C and an assumption is made that handling time is brief or negligble, then:

$$C = QP^{-m} \qquad (2) .$$

If handling time is not removed from the measure of consumption, m will be underestimated. Northern squawfish capture and swallow smolts rapidly and several smolts are often captured in rapid succession (Petersen and DeAngelis 1992; personal observations), so we assumed that handling time can be ignored and equation 2 can be used to test for potential compensation.

Tests -- Tests will be conducted on predation rate (smolts eaten / predator / d) and on the change in predator diet. All data will be partitioned as described above (tailrace, mid-reservoir, forebay).

Average consumption rates C (C>0) will be regressed against local predator density P using the logarithmic form of equation 2. Regression slopes (m) that are significantly ($P<0.05$) less than zero would be an indication of potential compensation. If interference is detected (m<0) other questions will be addressed concerning predator size and area effects. Results of these analyses will be graphs and specific statistical tests of hypotheses.

An increase in the proportion of the diet of predators that was juvenile salmonids between a pre-removal and a post-removal period would also suggest compensatory feeding. We will contrast diets of northern squawfish during the early John Day Reservoir study (1983-86) with diets of northern squawfish during a post-removal period (1993-96) in John Day Reservoir. The methodology of Somerton (1990) will be applied, which uses a randomization procedure to compare diets. Large numbers of predators are available for these periods (>5000 for 1983-86 and >2000 for 1993-96) so we expect adequate sample sizes for these tests. Results will be a test of whether diets before removal were similar to diets observed after removal.

Data analyses will be conducted using the SAS statistical package (SAS 1985) and software from Somerton (1990) for diet tests.

f. Facilities and equipment.

Tasks for this project are primarily data manipulation and analysis; no field work is planned. Analytical tasks will be performed at the Columbia River Research Laboratory (CRRL) which has state-of-the-art computers, appropriate statistical software (e.g., SAS), and an adequate fisheries library. Journal articles not available at CRRL can be easily obtained from the University of Washington or Oregon State University. Some data necessary to perform the planned analyses will be requested from ODFW. No special or high-cost equipment is needed.

g. References.

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Beamesderfer, R. C., D. L. Ward, A. A. Nigro. 1996. Evaluation of the biological basis for a predator control program on northern squawfish (*Ptychocheilus oregonensis*) in the Columbia and Snake rivers. Can. J. Fish. Aquat. Sci. 53:2898-2908.

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Mesa, M. G., T. P. Poe, D. M. Gadomski, and J. H. Petersen. 1994. Are all prey created equal? A review and synthesis of differential predation on prey in substandard condition. J. Fish Biol. 45:81-96.

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Petersen, J. H., and D. L. DeAngelis. 1992. Functional response and capture timing in an individual-based model: predation by northern squawfish (*Ptychocheilus oregonensis)* on juvenile salmonids in the Columbia River. Can. J. Fish. Aquat. Sci. 49:2551-2565.

Petersen, J. H. 1994. Importance of spatial pattern in estimating predation on juvenile salmonids in the Columbia River. Trans. Am. Fish. Soc. 123:924-930.

Petersen, J. H. 1997. Density-dependent predation: large-scale predator removal and local compensatory feeding on juveniles salmon (Abstract). Annual Meeting of the American Fisheries Society, Monterey, California.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120:405-420.

Poe, T. P., R. S. Shively, and R. A. Tabor. 1994. Pages 347-360 *in* D.J. Stouder, K. L. Fresh, and R. J. Feller, editors. Ecological consequences of introduced piscivorous fishes in the lower Columbia and Snake rivers. Theory and Application in Fish Feeding Ecology. University of South Carolina Press, Columbia.

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Ward, D. L., J. H. Petersen, J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Trans. Am. Fish. Soc. 124:321-334.

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Section 8. Relationships to other projects

Objective 1. The Northern Squawfish Management Program (Project 9007700) continues in 1998 and ODFW is continuing evaluation of the program, although at a reduced level. The objective we have laid out above should be complementary to the ongoing evaluation by answering an outstanding question about potential compensation. Results of these analyses may also be used to focus the management program in specific areas, if compensation is detected.

Objective 2. PATH analyses are being conducted through several projects (Projects 9600600, 9601700, 9600800). Specific tasks accomplished by funding USGS would strengthed the individual and overall PATH products. A specific example is cooperation by USGS/CRRL staff on the fall chinook analysis by PATH. Fall chinook may be especially susceptible to high predation losses because of their migration during summer months when temperatures are high. USGS/CRRL staff have expertise in both predation issues and in fall chinook biology (e.g., Petersen and DeAngelis 1992; Petersen 1994; Rondorf and Tiffan 1997). Staff are currently providing assistance to the fall chinook salmon workgroup, coordinated under Project 9601700. USGS will also be conducting field studies in the lower Snake River and in the Hanford Reach during 1998 (ACOE funded project) on predation and drawdown, and PATH has strongly supported this work (Marmorek 1997). Results of these studies will be provided to PATH as they accrue.

Section 9. Key personnel

Principal Investigator:	James H. Petersen, Ph. D. Research Fishery Biologist	0.5 FTE / 1,000 hrs

Dr. Petersen has conducted research on predation in the Columbia River Basin for the last 9 years. Additional staff from USGS/CRRL, such as Dennis Rondorf, Tom Poe, Dena Gadomski, and Matt Mesa, may be called upon to provide assistance to PATH.

Resume for: James H. Petersen

Experience

1995-Present	Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory, Cook, WA. Current responsibilities: Project leader on research project to determine survival of summer steelhead over their first winter in the Wind River Basin (WA). Co-leader on various mainstem Columbia and Snake River projects concerning juvenile salmon passage, predation, and reservoir drawdown.
1994	Acting Director, Columbia River Research Laboratory, USGS, Cook, WA.
1988-93	Research Fishery Biologist, Columbia River Research Laboratory, U.S. Fish and Wildlife Service.
1984-88	Associate Research Curator, Section of Fishes, Natural History Museum of Los Angeles County, Los Angeles, CA.
1983-84	Environmental Scientist, Section of Fishes, Natural History Museum of Los Angeles County.
1977-83	Graduate Teaching Assistant, University of Oregon, Eugene, OR.

Education:	School		Degree and Date Received
	University of Oregon, Eugene	Ph.D.	Marine Ecology, 1983
	University of Queensland, Australia		Rotary Fellowship, 1976
	Boise State University, Boise		B.S. Biology, 1975

Expertise: The primary areas of my expertise include predator-prey dynamics, population dynamics, and application of various modeling techniques to fisheries.

Publications and Reports (five most relevant)

Petersen, J. H. and D. L. DeAngelis. 1992. Functional response and capture timing in an individual-based model: predation by northern squawfish (*Ptychocheilus oregonensis*) on juvenile salmonids in the Columbia River. Can. J. Fish. Aquat. Sci. 49:2551-2565.

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Ward, D. L., J. H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Trans. Am. Fish. Soc. 124:321-334.

Petersen, J. H., and D. L. Ward. *In review*. Development and corroboration of a bioenergetics model for northern squawfish feeding on juvenile salmonids in the Columbia River. Trans. Am. Fish. Soc.

Section 10. Information/technology transfer

Objective 1. Results of analyses and conclusions will be submitted for publication in a peer-reviewed journal.

Objective 2. Technical analyses, data requests, etc. will be incorporated into PATH documents as appropriate.